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A Typology of Cluster Reduction: Conflicts with Sonority

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1. Introduction

A common pattern of onset cluster reduction is for the least sonorous member of the adult cluster to surface (e.g., Barlow, 1997; Chin, 1996; Gnanadesikan, in press; Goad & Rose, in press; Ohala, 1999). This pattern is exemplified in English data from a normally developing child in (1) and from a child with a phonological delay in (2). In (1a) and (2a), obstruent-sonorant clusters reduce to the obstruent, the segment of lower sonority, while in (1b) and (2b) fricative-stop clusters reduce to the lower sonority stop.

(1) Gitanjali (age 2;3 – 2;9; Gnanadesikan, in press)

a.	[kin]	'clean'	[dɒ]	'draw'	[piz]	'please'
	[so]	'snow'	[sɪp]	'slip'	[fɛn]	'friend'
b.	[gaɪ]	'sky'	[gɪn]	'skin'	[bɪw]	'spill'

(2) Subject 25 (age 4;10; Barlow, 1997)

a.	[din]	'queen'	[do]	'grow'	[beɪ]	'play'
	[sowɪŋ]	'snowing'	[sip]	'sleep'	[sip]	'sweep'
b.	[bun]	'spoon'	[daɪ]	'sky'	[dov]	'stove'

Several child phonologists have analyzed the preference for low sonority onsets as being due to a phonetically grounded fixed ranking of constraints (Barlow, 1997; Gnanadesikan, in press; Ohala, 1996; cf. Prince & Smolensky, 1993). One version of such a ranking (Pater, 1997) is shown in (3).

(3) *G-Ons >> *L-Ons >> *N-Ons >> *F-Ons
(Where G=Glide, L=Liquid, N=Nasal, F=Fricative)

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Position in this fixed ranking is correlated with the segments' sonority. Glides, being the most sonorous consonants, violate the highest ranked onset sonority constraint, and stops, being the least sonorous, violate no onset sonority constraint at all. When all else is equal, this hierarchy of constraints will select the lowest sonority onset as optimal, yielding the data pattern in (1) and (2).

Not all children follow the sonority pattern. In this paper, we apply two fundamental principles of Optimality Theory (Prince & Smolensky, 1993) to yield predictions about other children's cluster reduction patterns. The first principle is that of *factorial typology*, according to which all rankings of constraints should yield possible languages. To produce the sonority pattern, all conflicting constraints must rank beneath the onset sonority constraints. If they rank above the onset sonority constraints, conflicting constraints will force deviations from the sonority pattern. Here we focus on the constraints shown in (4), showing that they do have the expected effects in cluster reduction; see further Barlow (1997) and Pater and Barlow (2001) on MAX-LABIAL effects.

(4)	*Constraint*	*Effect in cluster reduction*	*Effect elsewhere*
	*FRICATIVE	/sn/ → [n]	/s/ → [t]
	*DORSAL	/kl/ → [l] (or [j])	/k/ → [t]

The second principle we appeal to is that of *emergent constraint activity*, according to which the effects of violated constraints may be observed when higher ranked conflicting constraints are not at issue. We show that even when the onset sonority constraints are outranked by the conflicting constraints in (4), under the right circumstances the sonority pattern does emerge.

2. *FRICATIVE Effects in Cluster Reduction

Children's early productions often display a pattern of "stopping," whereby fricatives are realized as stops (Ingram, 1974), as shown in the data from Amahl (Smith, 1973) at age 2;2 in (5):

(5) "Stopping" in Amahl's speech

[b̥ʌt]	'bus'	[d̥u]	'zoo'	[maip]	'knife'
[b̥ʌt]	'brush'	[ʌdə]	'other'	[b̥at]	'bath'

Since stopping applies in all environments (coda and onset), *F-ONS cannot be responsible for this pattern. Therefore, a context-free markedness constraint such as that in (6) is needed (Barlow, 1997):

(6) *FRICATIVE: Segments may not be *[+cont, -son]

To obtain the sonority pattern, *FRICATIVE must be ranked beneath the onset sonority constraints. For example, if *FRICATIVE is ranked above *N-ONS, nasals will be chosen instead of fricatives. The following tableaux compare the effects of the two rankings:

(7) a. *N-ONS >> *FRICATIVE

/snoʊ/	*N-ONS	*FRIC
[noʊ]	*!	
☞ [soʊ]		*

b. *FRICATIVE >> *N-ONS

/snoʊ/	*FRIC	*N-ONS
☞ [noʊ]		*
[soʊ]	*!	

The mapping of /sn/ to [s] in (7a) is the sonority pattern, illustrated in (1) and (2) above. The mapping of /sn/ to [n] in (7b) is also attested in many children's productions, as we will show in this section and in section 5 below.

A dramatic illustration of the effects of *FRICATIVE comes from data elicited from LP65, a child learning English (aged 3;8) with a phonological delay (see Barlow, 1997 for further subject details). For all adult fricative-sonorant clusters, LP65 produces the sonorant, as shown in (8).

(8) LP65: Target fricative-sonorant clusters

Type	*Child form*	*Adult gloss*	*Child form*	*Adult gloss*
fr	[wɛnd]	'friend'	[wʊːt]	'fruit'
sl	[jip]	'sleep'	[jɛd̥]	'sled'
sn	[niːd]	'sneeze'	[noʊmæn]	'snowman'
ʃr	[wɪnːt]	'shrink'	[wɛːd̥]	'shred'
sw	[wɪːn]	'swing'	[wɪəm]	'swim'
sm	[mɛʊ]	'smell'	[maɪjʊ]	'smile'
θr	[wi]	'three'	[woʊ]	'throw'

This pattern is produced if *FRICATIVE dominates all of the onset sonority constraints. The tableau in (9) establishes the ranking of *FRICATIVE above *G-ONS. (An undominated *LIQUID constraint is also necessary to account for gliding patterns in LP65's system (Barlow, 1997).)

(9) *FRICATIVE >> *G-ONS

/slip/	*FRIC	*G-ONS
[sip]	*!	
☞ [jip]		*

All of the constraints we have discussed thus far would be satisfied if the fricative were realized as a stop. The faithfulness constraint in (10) (McCarthy & Prince, 1999), however, would be violated:

(10) IDENT–CONTINUANT: Segments have identical [+/-cont] values in Input and Output

For LP65, IDENT-CONT must dominate *G-ONS, so that a glide surfaces rather than a "stopped" version of the fricative, as in (11):

(11) IDENT-CONT >> *G-ONS

/slip/	IDENT-CONT	*G-ONS
[tip]	*!	
☞ [jip]		*

It is not uncommon for children to produce the stop candidate in this situation, thus providing evidence of the reverse ranking (*G-ONS >> IDENT-CONT).

LP65 does produce singleton fricatives as stops, indicating that IDENT-CONT is itself dominated by *FRICATIVE. The word-final consonant in (12) illustrates this:

(12) *FRICATIVE >> IDENT-CONT

/sniz/	*FRIC	IDENT-CONT
☞ [nid]		*
[niz]	*!	

In LP65's system, we thus have a "conspiracy" between stopping of singleton fricatives and deletion of fricatives from clusters as means of satisfying *FRICATIVE. To complete the account, deletion must be ruled out for singletons. Deletion violates MAX (McCarthy & Prince, 1999), defined in (13). The tableau in (14) shows the effect of its ranking above IDENT-CONT:

(13) MAX: Every Input segment must have an Output correspondent

(14) MAX >> IDENT-CONT

/sniz/	MAX	IDENT-CONT
☞ [nid]	*	*
[ni]	**!	

The single violation of MAX in the optimal candidate in (14) is incurred to satisfy a higher ranked *COMPLEX constraint, defined in (15). Even though MAX is dominated by *COMPLEX, it has the effect of ruling out deletion of both segments of a cluster, as shown in (16). The rankings discussed above choose deletion of the fricative rather than deletion of glide, or stopping of the fricative.

(15) *COMPLEX: No onset clusters

(16) *COMPLEX >> MAX >> *G-ONS

/slip/	*COMPLEX	MAX	*G-ONS
[sjip]	*!		
[ip]		**!	
☞ [jip]		*	*

The conspiracy between fricative deletion and stopping in LP65's system is thus produced by the dominance of *FRICATIVE over both the onset sonority constraints and IDENT-CONT, as in the hierarchy in (17).

(17) Ranking of *FRICATIVE for LP65
*FRICATIVE, COMPLEX >> MAX >> IDENT-CONT >> *G-ONS

The ability to formally express conspiracies of this sort is an important virtue of constraint-based theories, and sets them apart from a purely rule-based framework. Smith (1973) in fact explicitly notes that his rule-based analysis failed to capture the fact that several of Amahl's rules had as a goal the elimination of clusters. This is also an advantage of the present analysis over the constraint-based one presented in Goad and Rose (in press). They treat avoidance of [s] in cluster reduction as due to head-faithfulness, rather than *FRICATIVE. Not only does this fail to extend to cases where *all* fricatives are deleted from clusters (as in LP65's data), but it also fails to relate this avoidance to the stopping pattern, and hence to express the conspiracy between the two phenomena.

3. *DORSAL Effects in Cluster Reduction

Another constraint that conflicts with sonority-based onset selection is *DORSAL (Barlow, 1997; Prince & Smolensky, 1993), defined in (18). In child phonology, this constraint is responsible for "fronting," as in (19).

(18) *DORSAL: Consonants are not specified as dorsal (velar)

(19) "Velar fronting" in LP65's speech

[d̥ɔb]	'cob'	[dʌt]	'duck'
[deɪː]	'gate'	[wædin]	'wagon'

In the case of velar-initial clusters, the sonority pattern depends on *DORSAL being dominated by onset sonority constraints, as illustrated in (20):

(20) *L-ONS >> *DORSAL

/klin/	*L-ONS	*DORSAL
[lin]	*!	
☞ [kin]		*

In LP65's phonology, however, this constraint dominates the onset sonority constraints, as evidenced by the data in (21), and the tableau in (22).

(21) LP65: Target velar-initial clusters

Type	*Child form*	*Adult gloss*	*Child form*	*Adult gloss*
gl	[jʌː]	'glove'	[joʊb]	'globe'
kl	[jin]	'clean'	[joʊː]	'clothes'

(22) *DORSAL >> *G-ONS

/gloʊb/	*DORS	*G-ONS
☞ [joʊb]		*
[g̥oʊb]	*!	

Here we have a conspiracy between fronting and deletion as responses to *DORSAL, which can be treated in the same way as the *FRICATIVE conspiracy. This involves appealing to the constraint IDENT-PLACE, as defined in (23). Two representative tableaux in (24) and (25) illustrate the conspiracy.

(23) IDENT-PLACE: Consonants have identical place of articulation in Input and Output

(24) *DORSAL, MAX >> IDENT-PLACE

/kɔb/	*DORSAL	MAX	IDENT-PLACE
[kɔb]	*!		
☞ [d̥ɔb]			*
[ɔb]		*!	

(25) IDENT(PLACE) >> *G-ONS

/gloʊb/	IDENT-PLACE	*G-ONS
☞ [joʊb]		*
[d̥oʊb]	*!	

Again, the reverse ranking of the IDENT constraint and *G-ONS is attested, in that some children produce fronted velars in cluster reduction (see (1) above).

The conspiracy between fronting and deletion of velars in LP65's system is thus captured by having *DORSAL outrank both IDENT-PLACE and *G-ONS, as in (26):

(26) Ranking of *DORSAL in LP65's system
*DORSAL, MAX >> IDENT-PLACE >> *G-ONS

4. Emergent Constraint Activity

The onset sonority constraints are dominated by a number of conflicting constraints in LP65's phonology. Here we have seen the effects of dominant *FRICATIVE, *DORSAL, and the associated faithfulness constraints IDENT-CONT and IDENT-PLACE. In addition, a dominant MAX-LABIAL constraint forces the preservation of a labial sonorant instead of a non-labial obstruent (e.g. /twɪn/ → [wɪn]; see Barlow (1997) and Pater and Barlow (2001) for details).

Nevertheless, the onset sonority constraints do continue to play a role, in just those circumstances in which the higher ranked constraints do not determine the outcome. This occurs when the consonants in the cluster are both labials, and neither one is a fricative, as shown in (27):

(27) Effects of onset sonority constraints in LP65's system

Type	*Child form*	*Adult gloss*	*Child form*	*Adult gloss*
br	[bɛd]	'bread'	[bʌʔ]	'brush'
pr	[b̥ɪɾi]	'pretty'	[b̥aɪ]	'prize'

The tableau in (28) shows how *G-ONS is able to exert its influence in this situation. Neither *FRICATIVE nor *DORSAL is relevant, and MAX-LABIAL is equally violated by the deletion of either consonant. The decision is thus passed down to *G-ONS, which prefers preservation of the stop.

(28) *FRICATIVE, *DORSAL, MAX-LABIAL >> *G-ONS

/brɛd/	*FRIC	*DORS	MAX-LAB	*G-ONS
[wɛd]			*	*!
☞ [bɛd]			*	

While *G-ONS is violated in many of LP65's productions, it is still visibly active when unimpeded by the demands of higher ranked constraints. This is the predicted outcome in a system of ranked constraints, but this sort of an emergent constraint effect is beyond the scope of other constraint-based theories, insofar as they allow constraints only to be on or off (in child phonology, see further Gnanadesikan, in press; Pater, 1997).

5. Further Factorial Typology

In the preceding sections we presented a child's system in which conflicting constraints outrank the entire onset sonority hierarchy, neutralizing their effects except when the higher ranked constraints are inapplicable. Factorial typology generates other predicted systems when the conflicting constraints occupy intermediate positions within the onset sonority hierarchy. An examination of the full factorial typology goes beyond the scope of this paper, but we will present here some preliminary results regarding the interaction of *FRICATIVE with the onset sonority hierarchy.

Table 1 provides the entire factorial typology produced by ranking *FRICATIVE with the onset sonority constraints. Beside the rankings are the predicted outcomes of reduction for fricative initial clusters of various sonority profiles. As *FRICATIVE ascends the hierarchy, segments of increasing sonority are chosen instead of the fricative. The first two rankings produce the sonority pattern, while the last one is that of LP65. The intermediate rankings are those in which the sonority pattern is only partially subverted.

Table 1. Factorial typology of *FRICATIVE and onset sonority constraints

		sw	sl	sn	st
a.	*G-ONS >> *L-ONS >> *N-ONS >> *F-ONS >> ***FRIC**	s	s	s	t
b.	*G-ONS >> *L-ONS >> *N-ONS >> ***FRIC** >> *F-ONS	s	s	s	t
c.	*G-ONS >> *L-ONS >> ***FRIC** >> *N-ONS >> *F-ONS	s	s	n	t
d.	*G-ONS >> ***FRIC** >> *L-ONS >> *N-ONS >> *F-ONS	s	l	n	t
e.	***FRIC** >> *G-ONS >> *L-ONS >> *N-ONS >> *F-ONS	w	l	n	t

The ranking of *FRICATIVE between *L-ONS and *N-ONS as in (c) of Table 1 appears to be quite common. For example, Julia and Trevor, two normally developing English-speaking children (Compton, 1970; Pater, 1997) consistently reduced fricative-nasal clusters to the nasal, as shown in (29) and (30). Trevor had one instance of reduction to the fricative out of 36 reduced fricative-nasal clusters; Julia had none. At the same time, they always reduced fricative-liquid clusters to the fricative, as in the examples in (31) and (32).

(29) Julia: Reduced fricative-nasal clusters

Type	*Child form*	*Adult gloss*	*Age*
sn	[mami+nis]	'mommy sneeze'	1;9.5
	[nek]	'snake'	1;11.22
sm	[ʍʌs ai meʊ]	'what (do) I smell?'	2;4.28

(30) Trevor: Reduced fricative-nasal clusters

sn	[næ]	'snap'	1;1.4
	[mæp]	'snap'	1;8.12
	[niːz]	'sneeze'	1;10.5

(31) Julia: Reduced fricative-liquid clusters

Type	*Child form*	*Adult gloss*	*Child form*	*Adult gloss*
fl	[faʊwɚ]	'flowers'	1;11.23	
fr	[fɔgi]	'froggy'	2;0.23	
sl	[sip]	'sleep'	1;8.27	

(32) Trevor: Reduced fricative-liquid clusters

fl	[fəwə]	'flower'	1;7.6
fr	[faːg]	'frog'	1;10.5
sl	[siːp]	'sleep'	1;8.26

The tableaux in (33) show how the ranking of *FRICATIVE between the two onset sonority constraints yields this partially subverted sonority pattern:

(33) a. *L-ONS >> *FRICATIVE

/slip/	*L-ONS	*FRIC
☞ [sip]		*
[lip]	*!	

b. *FRICATIVE >> *N-ONS

/snek/	*FRIC	*N-ONS
☞ [nek]		*
[sek]	*!	

In the child data available to us, we have not found evidence of the other intermediate ranking of *FRICATIVE (pattern (d) in Table 1). Goad and Rose (in press), however, provide an alternative analysis of what they term the "head pattern" of cluster reduction that relies on a ranking of IDENT-CONT between two *L-ONS constraints, one banning rhotics and the other banning laterals. Though Goad and Rose ultimately reject this analysis, it does remain tenable, and from the present perspective provides another instance of the sonority pattern being partially disrupted by having a conflicting constraint ranked within the onset sonority hierarchy.

A number of putative onset selection patterns are predicted to be impossible in this account. The fixed ranking of onset sonority constraints yields the implicational prediction in (34):

(34) If a segment of a given sonority is chosen instead of the fricative, then all segments of lesser sonority will also be chosen instead of the fricative

Hypothetical patterns of cluster reduction that run counter to the prediction in (34) are presented in Table 2. Note that some of these might be produced with the inclusion of other constraints. Patterns (c) and (e) are produced by the inclusion of MAX-LABIAL (mentioned in the preceding section; see Pater & Barlow, 2001): (C) is Julia's pattern, but we have yet to find a child displaying (e). None of the other patterns are attested in the data we have seen.

Table 2. Patterns of cluster reduction predicted to be impossible

	sw	sl	sn	st
a.	w	l	n	s
b.	w	l	s	t
c.	w	s	n	t
d.	w	l	s	s

	sw	sl	sn	st
e.	w	s	s	t
f.	w	s	n	s
g.	s	l	n	s
h.	w	s	s	s

	sw	sl	sn	st
i.	s	l	s	s
j.	s	s	n	s

Thus, almost all of the patterns predicted by factorial typology are attested, while none of the patterns predicted to be impossible are (again, excepting (c) and (e)). We believe that this provides considerable initial support for this approach.

There is at least one attested pattern of cluster reduction that is not generated by the set of constraints considered in this paper. This pattern was observed in the data of a normally developing two-year-old male who consistently retained the initial consonant of the cluster, regardless of the sonority (see Stoel-Gammon, 1985 on data collection procedures):

(35) M8 at 24 months

Type	*Child form*	*Adult gloss*	*Type*	*Child form*	*Adult gloss*
bl	[beŋki]	'blanket'	br	[bok]	'broke'
dr	[dɪŋk dɪs]	'drink this'	gr	[gæmə]	'grandma'
pl	[pet]	'plate'	sk	[sul bəs]	'school bus'
st	[sov]	'stove'	sp	[fətiya]	'spatula'

This suggests the activity of a constraint demanding retention of word-initial consonants, formalized in terms of positional faithfulness (Beckman, 1997) or anchoring (McCarthy & Prince, 1999).

Some further evidence for the activity of such a constraint comes from an examination of the frequency of deletion of either C1 or C2 in clusters of various sonority profiles. We examined reduced clusters in two corpora. Corpus 1 consisted of naturalistic production data by 24 children learning American English, sampled at both 21 and 24 months of age (Stoel-Gammon, 1985). Corpus 2 consisted of elicited production data from children 42 learning American English with phonological delay (see Gierut, 1985 on data collection procedures). We held the fricative constant (always [s]) and varied the sonority of C2 (thus, 'st' = [sp], [sk], and [st], 'sn' = [sn], [sm], 'sl' = [sl], 'sw' = [sw]). The resulting frequencies of C2 deletion in cluster reduction are shown in (36).

(36) Frequency of C2 deletion in cluster reduction

a. Corpus 1

sw	sl	sn	st
n/a	100%	67%	15%
	18/18	4/6	10/68

b. Corpus 2

sw	sl	sn	st
70%	80%	50%	28%
47/67	28/35	34/68	31/112

For 'st' clusters, the sonority pattern was the most common. However, a number of the productions retained the fricative, which would be unexpected if there were no constraint favoring that outcome.

It is also notable that the sonority of C2 is generally correlated with its frequency of deletion, which supports the role of the onset sonority hierarchy in determining the choice of the segment in cluster reduction (see also an experimental study by Ohala, 1999). However, sonority does not seem to be the sole determinant of the outcome, as can be seen especially in the 'sn' clusters. While we must leave the modeling of the quantitative data for future work (cf. Pater & Werle, 2001; Smolensky, Davidson, & Jusczyk, in press), these figures do seem consistent with the interaction of a fixed onset sonority hierarchy with a set of conflicting constraints.

6. Conclusions

We have shown that several independently motivated markedness and faithfulness constraints do interact with the onset sonority hierarchy in the manner predicted by Optimality Theory. When these conflicting constraints are dominant, they override the sonority constraints, producing attested patterns of onset cluster reduction. The outranked onset sonority constraints do continue to play a role in that their effects emerge when the higher ranked constraints are not decisive. While it will take further research to determine whether the entire factorial typology produced by the various permutations of these constraints does match the attested child data, the initial results are promising.

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